CLAIMS

WE CLAIM:

1. A multiple fiber optic apparatus comprising:

a) a crystal substrate having a first surface;

b) a first array of grooves etched into said first surface;

c) a second array of side-polished optical fibers held within said first array of grooves,

wherein said array of side-polished optical fibers held within the common substrate form a mechanically integrated set of fiber optic apparatuses which may be of different types.

2. The multiple fiber optic apparatus of claim 1, wherein at least two of said side-polished optical fibers are actually continuous parts of a single fiber looped around to pass through at least two of the grooves in said array of grooves.

3. The multiple fiber optic apparatus of claim 1, wherein two or more of said grooves are at least partially formed along 111 Miller planes of the crystal substrate.

4. The multiple fiber optic apparatus of claim 1, wherein said crystal substrate is one of the group including silicon, GaAs, lithium-niobate ($LiNbO3$), potassium dihydrogen phosphate (KDP), lithium tantalate ($LiTaO_3$), barium titanate ($BaTiO_3$), silicon germanium (SiGe), indium phosphide (InP), gallium indium arsinide (GaInAs), a III-V compound, and an organic crystal.

5. The multiple fiber optic apparatus of claim 1, wherein at least one of the optical fibers forms one of the group

including an optical pass-through, an attenuator, a polarizer, a filter, a modulator, and a switch.

6. The multiple fiber optic apparatus of claim 1, wherein at least one of the optical fibers is part of one of the group including a coupler, an add-drop multiplexer, a tap, a splitter, a joiner, a filter, a modulator or a switch

7. An integrated multiple fiber optic apparatus comprising:

(a) at least two substrates, wherein each said substrate has a first surface with a first array of grooves suitable for holding an array of side-polished fiber optics; and

(b) at least one array of side-polished fiber optics sandwiched within and between said grooves of two said substrates;

wherein said first surfaces of said two substrates are positioned substantially plane-parallel and facing one another, and

wherein the two arrays of grooves are aligned substantially opposite to one another.

8. The integrated multiple fiber optic apparatus of claim 7, wherein at least one of said side-polished fiber-optics is a 4-port apparatus.

9. The integrated multiple fiber optic apparatus of claim 8, wherein at least one of said 4-port apparatuses is one of the group including a coupler, add-drop multiplexer, tap, splitter, joiner, filter, modulator or switch.

10. A multiple fiber optic apparatus comprising:

(a) at least a first fiber;

(b) two or more side-polished areas along said first fiber;

(c) two or more substrate portions, with one associated with each said side-polished area;

wherein there are no splices or connectors used along said first fiber between at least two of said substrate portions associated with said side-polished areas.

11. The multiple fiber optic apparatus of claim 10 further including a substrate strip, wherein said two or more substrate portions are common to said substrate strip.

12. The multiple fiber optic apparatus of claim 11, wherein said first fiber forms at least one loop between two of said substrate portions.

13. The multiple fiber optic apparatus of claim 12 further including at least one additional fiber that forms half of a 4-port apparatus with the first fiber.

14. The multiple fiber optic apparatus of claim 13 forming an optical add-drop multiplexer.

15. A multiple fiber optic apparatus comprising:

(a) multiple substrate strips; and

(b) multiple side-polished fiber optic apparatuses sandwiched between pairs of said substrate strips;

wherein the substrate strips are stacked into a compact array; whereby a two-dimensional array of fiber optic apparatuses is achieved.

16. A freestanding, 2-port, side-polished, fiber optic apparatus comprising a fiber having a side-polished area.

17. The freestanding, 2-port, side-polished, fiber optic apparatus of claim 16 further including one or more thin films over said side-polished area.

18. A freestanding, 4-port, side-polished, fiber optic apparatus comprising:

(a) two fibers each having a side-polished area;

(b) a bonded interface between said side-polished areas.

19. The freestanding, 4-port, side-polished, fiber optic apparatus of claim 18 further including one or more thin films in said bonded interface between said side polished areas.

20. The freestanding, 4-port, side-polished, fiber optic apparatus of claim 18 further including a single substrate bonded to one of said fibers.

21. A method of manufacturing at least one 4-port, side-polished, fiber optic apparatus comprising:

(a) providing a first and second optical fiber;

(b) providing a first substrate having a first surface and a first groove within said first surface;

(c) providing a first, second and third bonding material;

(d) using said first bonding material to hold said first optical fiber within said first groove on said first surface of said first substrate;

(e) removing the side-wall of said first optical fiber by polishing to create a first side-polished area of said first optical fiber;

(f) using said second bonding material to hold said second optical fiber within said second groove on said second surface of said second substrate;

(g) removing the side-wall of said second optical fiber by polishing to create a second side-polished area of said second optical fiber;

(h) bonding together said first and second side-polished areas using said third bonding material; and

(i) removing said second bonding material;

whereby the first and second optical fibers remain bonded together at their side-polished areas, supported by said first substrate and free of said second substrate.

22. The method of claim 21, further including subsequent reuse of said second substrate.

23. The method of claim 21 further including its repetition at another location along at least one of the fibers.

24. The method of claim 21 further including removing said first bonding material, whereby the first and second optical fibers remain bonded together at said side-polished areas and free of both of the substrates.

25. The method of claim 21, wherein said first and second bonding materials are the same type and are removed substantially simultaneously.

26. The method of claim 21, wherein said second bonding material can be softened by heating.

27. The method of claim 21, wherein said second bonding material can be removed using a solvent.

28. The method of claim 21, wherein said third bonding material is UV-curing material.

29. The method of claim 28, wherein UV radiation is delivered to expose said third bonding material by way of an optical fiber.

30. A method of manufacturing at least one 4-port, side polished, fiber optic apparatus comprising:

(a) providing a first and second optical fiber;

(b) providing a first substrate having a first surface and a first groove within said first surface;

(c) providing a second substrate having a second surface and a second groove within said second surface;

(d) providing a first, second, third, fourth, and fifth bonding material;

(e) using said first bonding material to hold said first optical fiber within said first groove;

(f) using said second bonding material to hold said second optical fiber within said second groove;

(g) removing the side-wall of said first optical fiber by polishing to create a first side-polished area;

(h) removing the side-wall of said second optical fiber by polishing to create a second side-polished area;

(i) removing said first and second bonding materials;

(j) using said third bonding material to hold said first optical fiber within said first groove, wherein said third bonding material is kept away from said first side-polished area;

(k) using said fourth bonding material to hold said second optical fiber within said second groove, wherein said fourth bonding material is kept away from said second side-polished area;

(l) bonding together said first and second side-polished areas using said fifth bonding material; and

(m) removing said fourth bonding material;

whereby the first and second optical fibers remain bonded together at their side-polished areas and supported by only the first substrate, and wherein said second substrate is freed.

31. The method of claim 30 further including removing said second bonding material, whereby said first and second optical fibers remain bonded together at their side-polished areas and are free of both substrates.

32. A method of simultaneously fabricating an array of 4-port side-polished fiber optic apparatuses comprising:

(a) providing a first array of side-polished optical fibers, wherein each of the fibers has a first side-polished area lying in the plane of a first surface of a supporting first substrate;

(b) providing a second array of side-polished optical fibers, wherein each of the fibers has a second side-polished area lying in the plane of a second surface of a supporting second substrate;

(c) aligning said first and second arrays such that said first and second side-polished areas pair up respectively in contact with one another; and

(d) bonding together said first and second surfaces.

33. The method of claim 32 wherein said aligning is at least partially accomplished using at least one additional fiber as a locating key sandwiched between two grooves.

34. A method of aligning and placing an array of two or more fibers into an array of at least as many grooves, the method comprising:

(a) providing an array of fibers;

(b) providing a first array of parallel grooves which all lie in a first plane, are spaced apart from one another with a first pitch, and have at least a first set of open ends that taper to be wider toward said ends;

(c) providing a clamping and holding tool having a second array of parallel grooves which all lie in a second plane and are spaced apart from one another with a second pitch equal to said first pitch;

(d) providing a pushing tool, wherein said pushing tool has a soft and compliant edge;

(e) clamping said array of fibers into said second array;

(b) orienting and positioning said clamping and holding tool to place said second plane at an angle to said first plane;

(c) moving said array of fibers, while held in said clamping and holding tool, up against said set of open ends of said first array of parallel grooves;

(d) reducing said angle to zero while gently urging the compliant edge of said pushing tool against said array of fibers, toward said first array of parallel grooves.

35. The method of claim 34 wherein said urging includes beginning at said open ends and includes sliding along said first array of parallel grooves away from said open ends as said angle approaches zero.

36. A method of facilitating the parting of two face-to-face substrate surfaces sandwiching at least one 4-port side-polished fiber optic apparatus, the method comprising adding at least one groove in at least one of the substrate surfaces, whereby air or other gas can more easily enter between said surfaces.

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